UNITED STATES PATENT APPLICATION FOR

CONFIGURATIONS FOR COLOR DISPLAYS BY THE USE OF LENTICULAR OPTICS

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TITLE OF THE INVENTION

CONFIGURATIONS FOR COLOR DISPLAYS BY THE USE OF
LENTICULAR OPTICS

5 ## INVENTORS

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FIELD OF THE INVENTION

10   The present invention is directed towards the optics

of luminance-chrominance systems for projection displays.

BACKGROUND OF THE INVENTION

Optical projection systems in which the image is

generated by light modulated by one or more "lightvalves"

are becoming increasingly common. Devices such as

televisions, presentation projectors and computer

monitors have utilized such lightvalve based projection

systems. Typically, in a single lightvalve system, a

color image is produced by projecting red (R), green (G)

20   and blue (B) (collectively referred to as "primary"

hereinafter) image fields in a time sequential manner

with sufficient rapidity that flicker is not apparent.

The overall frame rate desired for color images is

typically 60 Hertz or greater. Thus, the corresponding

25   interval between each color image field is 1/180th of a

second or less.

Single lightvalve systems such as those used in

LCD (Liquid Crystal Display) projection systems are

relatively inexpensive and the resulting performance is satisfactory. However, an inherent drawback of time sequential lightvalve and other systems is an effect known as 'color breakup artifact' or 'field sequential

5   color artifact'. Color breakup artifact manifests itself to a viewer as a transient rainbow-like fringing effect when rapid eye movements of several degrees are made. The effect is an inherent property of the human visual system but sensitivity to the effect varies greatly from

10   person to person. Moreover, the seriousness of the effect depends strongly on the nature of the image being viewed.

        An important issue in evaluating projection system methods is the total number of pixels required, because the cost and complexity of the display normally increase

15   as the number of pixels required increases. In describing various projection systems it is convenient to express the number of pixels as a multiple of the number, N, which is the required number of pixels in the field sequential projection system. In addition to the

20   number of pixels, the final screen luminance should be high enough so that it matches or exceeds the luminance provided by other display systems under commercialization. The final screen luminance of the whites of a projection system, can be expressed as a

25   function of L, the final screen luminance of a field

sequential projection system using a single reflecting
lightvalve array with a polarizing cube.

A number of methods which have been traditionally
used include the use of a separate projection system for
each of red, green and blue lamps, or a single lamp with
dichroic mirrors providing three separate red, green and
blue beams. Another set of methods uses a large mosaic
filter with a reflecting lightvalve array and polarizing
beamsplitter.

Figures 1-4 show some of these methods that may be
employed in projection systems. Projection system 100 of
Figure 1 uses three lamps (e.g. projection cathode-ray
tubes) 110 to achieve the projection of red, green, and
blue images in register on a reflecting or on a
translucent screen. This has achieved commercial
success, but the cost is high. The light from lamps 110
are filtered by interference filters 120, three in
number, which will each increase the luminance of the
red, green and blue beams as compared to when using dye-
based filters. The red, green and blue light beams
resulting from the filtering are each passed thru
condensers 130. Condensers 130 are a series of lensing
elements that make the light beams spatially uniform
(i.e. even out the power of light across the area of the
beam). In projection system 100, three lightvalve arrays

140 are used, each within its own beam area, to project

red, green, and blue images in register on a translucent

screen 160. With the aid of projection lenses 150, the

light from the arrays is focused and thus combined onto a

5   single RGB point on screen 160. Registration problems

can be reduced by using reflecting arrays since their

size can be small compared to the size of the final

image. The number of required pixels is 3N.

Alternatively, as shown in **Figure 2**, the light from

10   a single lamp is 210 split into red, green, and blue

components by three dichroic mirrors 215. The light from

dichroic mirrors 215 are filtered by interference filters

220, three in number, which will each increase the

luminance of the red, green and blue beams as compared to

15   when using dye-based filters. The red, green and blue

light beams resulting from the filtering are each passed

thru condensers 230 which make the beams of light

spatially uniform. In projection system 200, three

lightvalve arrays 240 are also used, each within its own

20   beam area, to project red, green, and blue images in

register on a translucent screen 260. With the aid of

projection lenses 250, the light from the arrays are

focused onto a single RGB lumen on screen 160.

Both projection systems 100 and 200 suffer the cost

25   disadvantages of having three lightvalve arrays and three

lenses, of maintaining the registration of the three

projected images. The number of total pixels for

projection system 200 is again 3N as with the three lamp

system 100 of **Figure 1**. Compared with the prism assembly

5   method (shown below in **Figure 4**), potential advantages

are that, if three lamps are used as in system 100, the

light output is tripled; or if one lamp is used with

beam-splitting dichroic mirrors as in system 200, they

are less costly to assemble and manufacture than the

10   prism assembly methods.

An alternative approach is to abandon time

sequential imaging while still using only one lightvalve

by presenting the primary colors to the viewer in the

space domain, rather than in the time domain. One way of

15   constructing such a field sequential system would be to

arrange the R, G and B pixels in a mosaic pattern, like

the arrangement of phosphor spots in a Cathode Ray Tube

device. The lightvalve would be illuminated using white

light, and each R pixel would be covered with a red

20   filter, each G pixel with a green filter and each B pixel

with a blue filter. The requisite filter array would

contain about 10^6 or more filters. Furthermore, in the

case of a micro-display lightvalve array, each filter

would measure only 10x10 μm^2. Though conceptually easy,

25   implementing such large filter arrays and such small

individual filters could be prohibitively expensive. Disadvantageously, mosaic filter arrays need about three times as many pixels.

Figure 3 shows one such mosaic filter 300 that can be employed in a projection system. Mosaic filter 300 contains a pattern of red, green and blue pixel locations. In light-sensitive arrays (such as CCD arrays) more green cells are usually incorporated than red or blue cells. Where required mosaic filter 300 may instead be composed of cyan, magenta, yellow, and green cells or any combination of colors. For most displays, the relative numbers of red, green, and blue cells have to be chosen to maximize the luminance of the display and to keep the total number of cells to a minimum. To meet these requirements an equal number of red, green, and blue cells are used as in the case of mosaic filter 300.

Single transmitting LCD arrays, covered with a mosaic of red, green, and blue filters, such as filter mosaic 300, provide either panel displays illuminated by fluorescent lamps or projected displays by means of overhead projectors. In projection system 400 of **Figure 4**, a reflecting LCD array 430 is used with mosaic filters 440 to provide a projected image based on light originating from a single lamp 410. Reflecting array 440 is used because its small size makes a compact projector

possible. Condenser 420 makes the light from lamp 410 to
be spatially uniform. Field lens 450 transmits the image
onto the appropriate position on projection lens 490.
The image rays are first passed through a polarizing cube
5   470 which allows any light arriving in a given direction
X to pass through its hypotenuse while reflecting back
any light perpendicular to that direction X. The
projection lens 490 focuses the filtered light output
from polarizing cube 470 onto a screen or other
10   destination (not shown). Some advantages of projection
system 400 are that only one light-valve array is used,
no temporal color break-up can occur, and no prism
assembly is required. A disadvantage is that the filters
440 have to be made of dyes and thus have lower
15   transmittances than the interference filters used in the
filter wheel of the field sequential system or in the
dichroic elements of the prism assembly. The number of
pixels required for this mosaic method is usually 3N.

One other arrangement of avoiding the mosaic filters
20   is to provide a rapidly revolving red, green, and blue
filter wheel in front of a single reflecting LCD array
with a polarizing beam-splitting cube. The use of a
reflecting array makes it possible to incorporate micro-
circuits beneath the pixels without loss of light; and
25   illuminating them with a polarizing beam-splitter cube

makes for a convenient and efficient arrangement.

However, the field sequential system provided by the

rotating filter wheel results in disturbing color break-

up for some observers. The use of three lightvalve

5 arrays, with a dichroic prism assembly to combine the

three images, avoids the color break-up, but involves the

added costs of two extra arrays and the prism assembly.

Alternative methods of projecting images, using

lightvalve arrays to produce color displays, are

10 therefore of interest.

SUMMARY

The invention in one or more embodiments consists of a lenticular array and one or more lightvalves together with lens filters that serve to synthesize mosaic filters in an optical projection system that produces an image.

In various embodiments, the filters correspond and align with the shape and configuration of lenticules in the lenticular array. Also, in various embodiments, the lightvalves may be of a transmitting or reflecting type and in most embodiments, the lenticular array is built onto one of the lightvalves. Further, in various embodiments, the luminance and chrominance components of the image to be projected may be processed into separate signals.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 illustrates a typical triple projection system using three lamps.

Figure 2 illustrates a typical triple projection system using one lamp.

Figure 3 illustrates a typical filter mosaic utilized in a typical LCD array based projection system.

Figure 4 illustrates a typical single LCD transmitting array based projection system.

Figure 5 illustrates the optical principles underlying a lightvalve and lenticular array based projection system in accordance with one or more embodiments of the invention.

Figures 6(a)-(b) illustrate various lenticules that may be employed in one or more embodiments of the invention.

Figure 7(a)-(c) illustrates various filters that may be employed in one or more embodiments of the invention.

Figure 8 illustrates a cylindrical Red, Green and Blue lenticular projection system with a transmitting lightvalve array.

Figure 9 illustrates a spherical lenticular projection system with a transmitting lightvalve array.

Figure 10 illustrates a cylindrical Red, Green and Blue lenticular projection system with a reflecting chrominance array and transmitting luminance array.

Figure 11 illustrates a cylindrical Red, Green and Blue lenticular projection system with a reflecting chrominance array and reflecting luminance array.

Figure 12 illustrates a cylindrical Red, Green and Blue lenticular projection system with a transmitting chrominance array and reflecting luminance array.

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DETAILED DESCRIPTION OF THE INVENTION

The invention is directed toward emulating a mosaic filter in a novel manner that also can reduce color breakup artifact. One or more embodiments described herein is a optical projection system with a lenticular array and a large filter which is placed at the projection lens' aperture stop.

Figure 5 illustrates the optical principles underlying a lightvalve and lenticular array based projection system in accordance with one or more embodiments of the invention. In optical projection system 500, the field lens 530 and projection lens 540 are assumed for clarity, to be ideal and thin. Also, to simplify the illustration, only rays that leave the lightvalve 510 parallel to the optic axis (OA) are shown.

The spacing between the field lens 530 and projection lens 540 is F, which (in this example) is equal to the focal length of the field lens. In optical projection system 500, it is assumed that the lenticular array 520 is cylindrical in composition, and that each lenticule is wide enough to cover three pixels (for instance, a1, a2 and a3), one of each primary color. The function of the lenticular array 520 is to ensure that, after passing through it, all of the R (Red) rays lie

within a single band of angles, independently of their starting point on the lightvalve 510, all of the G (Green) rays lie within a second band of angles, and all the B (Blue) rays within a third band of angles. In

5   **Figure 5**, for example, the angular bands, measured with respect to the optic axis, are approximately 37.5º to 12.5º for R, -12.5º to 12.5º for G and 12.5º to 37.5º for B.

The function of the field lens 530 is to transform

10   these angular ranges into spatial regions at the aperture stop of the projection lens 540. Thus, the R rays fill the lower third of the stop, the G rays the middle third (labeled Section 4), and the B rays the upper third (labeled Section 1). The filter 550 is placed at the

15   plane of the projection lens 540 and thus, also takes on three sections, the lower third being Red (R) and labeled Section 7, the middle being Green (G) and labeled Section 4, and the upper third being Blue (B) and labeled Section 1. Filter 550 consists of three differently colored

20   glasses: the R rays go through a red filter, the G rays through a green filter, and the B rays through a blue filter. In this way, the lenticular array 520, the field lens 530 and the filter 550 emulate the function of a mosaic filter array placed over the lightvalve 510.

Optical projection system 500 maps each pixel of the lightvalve into a corresponding location on screen 590. A portion of the lightvalve 510 shown in **Figure 5** is a vertical section through one column with each lenticule divided into three sections a_k, a_{k+1}, and a_{k+2} (where k is a non-zero whole number), which represent R, G and B rays, respectively. Optical projection system 500 has the following characteristics and parameters:

• The focal length of the lenticules (of any section of the lenticular array 520) into glass is f_1;

• The focal length of the lenticules (of any section of the lenticular array) into air is f_2.

• Thus, if the glass has a refractive index of Z, and the radius of curvature of each lenticule is R, then:

$$\frac{Z}{f_1} = \frac{1}{f_2} = \frac{Z-1}{R}$$

• The color filter 550 is placed at the plane of the projection lens 540 through its aperture stop. (In the case of a thick projection lens, it would be placed approximately at its principal plane.)

• The focal length of the field lens 530 is F, and the separation between the field lens 530 and projection lens 540 is also equal to F.

The rays emanating from pixels a1, a2 and a3 on the lightvalve 510 are assumed to be parallel to the optic

axis. The rays emanating from a1, a2 and a3 are brought
to a common image point A1-3 on the screen 590. In the
section shown, all the rays from a1 pass through the
region S4 in the plane of the projection lens 540. This
corresponds to Section 1 of the filter 550. Similarly,
the rays emanating from a2 pass through the region S3 in
the plane of projection lens 540, corresponding to
Section 4 of the filter 550. The rays emanating from a1
pass through the region S2 in the plane of projection
lens 540, corresponding to Section 7 of the filter 550.

Similar rays (i.e. rays parallel to the optic axis)
emanating from pixels a4, a5 and a6 are not depicted in
Figure 5, but given the optical characteristics of the
system, these rays are also brought to a common image
point on screen 590. All the rays emanating from a4 pass
through Section 7 of filter 550, those from a5 pass
through Section 4 and those from a6 pass through Section
1.

By induction, referring to **Figure 5**, in general:

•   All rays emanating parallel to the optic axis
from any group of three pixels served by the same
lenticule are brought to a common image point on screen
590.

•   All the rays emanating parallel to the optic
axis from pixels such as a1, a4, a7, . . . a(1+3n), where

n is an integer, pass through Section 7 of the filter
550.

•   All the rays emanating parallel to the optic
axis from pixels such as a2, a5, a8, . . . a(2+3n), where
n is an integer, pass through Section 4 of the filter
550.

•   All the rays emanating parallel to the optic
axis from pixels such as a3, a6, a9, . . . a(3+3n), where
n is an integer, pass through Section 1 of the filter
550.

Further, **Figure 5** has been drawn as an approximation
and is not to scale, but the optics therein should also
have these properties:

1)   The distance (D1) between the image point in
the plane of lightvalve 510 and the optic axis is
proportional to the distance (D2) between the central
pixel in the group of 3 and the optic axis in the plane
of the lightvalve 510; and

2)   The constant of proportionality between
distances D1 and D2 is equal to the magnification of the
projection lens.

Also, referring again to **Figure 5**, in general:

•   All the rays emitted from the centers of pixels
a1, a4, a7, ... a(1+3n), where n is an integer, pass
through the center of Section 7 of the filter 550.

- All the rays emitted from the centers of pixels a2, a5, a8, ... a(2+3n) pass through the center of Section 4 of the filter 550.

- All the rays emitted from the centers of pixels a2, a5, a8, ... a(2+3n) pass through the center of Section 1 of the filter 550.

For illustration, assume that a white area is being imaged. Then regions such as A13-15, A10-12, A7-9, A4-6, and A1-3 will be colored white, and the regions between them will (to first order) not be illuminated. Since patch A13-15 represents a combination of pixels a13, a14 and a15, and so on, this means that each group of 3 pixels (not the individual pixels themselves) of the lightvalve 510 is represented at the screen 590.

Figures 6(a)-(b) illustrate various lenticules that may be employed in one or more embodiments of the invention. If it is desirable to use spherical lensing elements, a spherical lenticule 610, such as that shown in **Figure 6(a)**, can be used in implementing a lenticular projection system. Each spherical lenticule 610 is situated above groups of four adjacent pixels that form a square in the lightvalve. This spherical lenticule 610 is repeated over an entire lightvalve. The spherical lenticule 610 should be dimensioned such that it covers precisely four pixels in a square. Of the four pixels in

each group which is covered by lenticule 610, in some

embodiments, one pixel carries a red signal, one pixel

carries a green signal, one pixel carries a blue signal,

and the fourth pixel carries either a red, or a green, or

5   a blue signal. In other embodiments the fourth signal

could be a pure white signal that enhances the luminance

of the final image. While increasing overall luminance,

White as the fourth signal cuts the saturation

(chrominance) available when compared to if white were

10   replaced by a filter of a primary color. If the

spherical lenticule 610 is used in constructing the

lenticular array, then any corresponding projection lens

should be covered with a four-part filter array. This

array should be oriented such that light rays from each

15   pixel in the groups of four (i.e. each of the four

sections in the spherical lenticule 610) passes through

only one part of the filter array. One advantage of

using spherical lenticule 610 is that pixels are square

in shape making their projection less complicated than

20   non-square pixels.

However, if it is desirable to use cylindrical

lensing elements, then a cylindrical lenticule 620, such

as that shown in **Figure 6(b)**, can be used in implementing

a lenticular projection system. Each cylindrical

25   lenticule 620 is situated above groups of three adjacent

pixels that form rectangular stripes in a lightvalve.

Cylindrical lenticule 620 is repeated over an entire

lightvalve. The cylindrical lenticule 620 should be

dimensioned such that it covers precisely three pixels in

5   stripes.

Of the three pixels in each group which is covered

by lenticule 620, one carries a red signal, one carries a

green signal, and one carries a blue signal. Each pixel

in each row would need to be three times as long in the

10   direction parallel to the lenticules as in the direction

at right angles to them, so that the format of the array

would not be altered. If the cylindrical lenticule 620

is used in constructing the lenticular array, then any

corresponding projection lens should be covered with a

15   three-part filter array.

In one implementation, such projection lens is

covered with a stripe (or segment) of red filter, a

stripe (or segment) of green filter, and a stripe (or

segment) of blue filter. Each of the stripes are of

20   equal width but, on a circular lens, the central stripe

is longer than the top and bottom stripes. It may

therefore be advantageous to use this stripe for the

color which is most limited for light. The stripes on

the lens are parallel to the cylindrical lenticules. The

25   set of lenticules can be parallel to the lines forming

the picture or at right angles to them, according to

whichever configuration is the more advantageous. Though

the pixel is rectangular in shape, the number of

requisite pixels can be only 3/4 of that of spherical

5   lenticule systems.

Figure 7(a)-(c) illustrates various filters that may

be employed in one or more embodiments of the invention.

RGB filter 710 of **Figure 7(a)** is composed of three

stripes, a first, topmost stripe carrying Green (G), a

10   second middle stripe carrying Red (R) and the third,

bottom stripe carrying Blue (B). The middle stripe is

longer than the top and bottom stripes, and can thus be

used for the color which is most limited for light, e.g.

Red. The RGB filter 710 would be fitted over a

15   projection lens in a projection system where the

lenticular array was cylindrical, and used lenticules

similar to lenticule 620 shown in **Figure 6(b)**.

RGB filter 720 of **Figure 7(b)** is composed of four

segments, each segment a one-quarter portion (i.e. a

20   quadrant of the circle) of the entire filter 720. The

top leftmost segment carries Red (R), the top rightmost

segment carries Green (G) while the bottom leftmost

segment carries Blue (B). In the configuration of filter

720, the bottom rightmost segment also carries a Red (R)

25   signal, such that if Red is the most light-limited, it

would yield a brighter projected image. In other

configurations, the arrangement of Red, Green and Blue

and duplication of one of the primary color signals may

be varied as required by the arrangement of pixels on the

5   lightvalve. Further, the choice of which primary to

repeat may depend upon the spectral composition of the

original light source. The RGB filter 720 would be

fitted over a projection lens in a projection system

where the lenticular array was spherical, and used

10   lenticules similar to lenticule 610 shown in **Figure 6(a)**.

In other embodiments, a four-part RGBW filter 730

(shown in **Figure 7(c)**) can instead be used in a

projection system that uses a spherical lenticular array.

RGBW filter 730 of **Figure 7(c)** is composed of four

segments, each segment a one quarter portion (i.e. a

quadrant of the circle) of the entire RGBW filter 730.

The top leftmost segment carries Red (R), the top

rightmost segment carries Green (G) while the bottom

leftmost segment carries Blue (B). In the configuration

20   of RGBW filter 730, the bottom rightmost segment also

carries a White (W) signal, which may thereby yield a

projected image with a greater luminance than a pure RGB

only system. In other configurations, the arrangement of

Red, Green and Blue and White color signals may be varied

as required by the arrangement of pixels on the

lightvalve.

Figure 8 illustrates a cylindrical lenticular

projection system with a transmitting array. Projection

5   system 800 consists first of a lamp 810 which is

typically a spherical light source with a reflector.

Lamp 810 sends light to a condenser 820 which refracts

that light such that it is spatially uniform and parallel

to the axis but with a range of angles typical of

10   condenser lenses. The light from the output of condenser

820 passes through a transmitting array 830.

Transmitting array 830 includes a lightvalve array

covered by a lenticular array, which in this embodiment,

has a field of cylindrical lenticules, such as the one

15   illustrated in **Figure 6(b)**.

In non-lenticular projection systems (e.g. slide or

motion projection systems), the red, green, and blue

exposures occur on the film at positions such that the

light, during projection, retraces its path.   There is

20   therefore no problem caused by the rays near the edges of

the picture not being at right angles to the lenticular

array. When using lenticules with a lightvalve array

(transmitting array 830), a field lens 840 is used to

ensure that the central beam to the projection lens is

25   always at right angles to the lenticules in all parts of

the picture. Alternatively, the lenticular array can be
used in the manufacture of the light valve pixels to
position them appropriately to allow for the angles of
the light at different parts of the picture.

5   The function of field lens 840 is to transform beams
of light filling certain angular bands into spatial
ranges at the aperture stop of a projection lens 860.
Light emerging from the field lens 840 is first passed
through filter 850. Since the lenticular array of the
10 transmitting array 830 consists of cylindrical
lenticules, filter 850 should be similar to filter 710
depicted in **Figure 7(a)**, and should have a stripe of Red,
Green and Blue for a total of three stripes. The
arrangement of these stripes would depend on the pattern
15 of the pixels in the transmitting array 830. The Red
rays will pass through the Red stripe of the filter 850,
the Blue rays will pass through the Blue stripe of filter
850 and the Green rays will pass through the Green stripe
of filter 850. The projection lens 860 focuses the
20 filtered light output from filter 850 onto a screen or
other destination (not shown). The three rays, Red,
Green and Blue, for a given pixel, are combined onto one
location on that screen/destination by the projection
lens 860. The lenticular array of transmitting array
25 830, the field lens 840 and filter 850, in combination

with one another serve to emulate a large mosaic filter

placed over a lightvalve array (as was depicted in **Figure**

3 and **Figure 4**) with less expense. Interference filters,

such as filter 850, may be used over the projection lens

5   860 to maximize their transmittance.

Projection system 800 is advantageous in that the

mosaic filter is avoided and replaced instead by embossed

lenticules (over the lightvalve array of transmitting

array 830). Compared to a field sequential projection

10   system, which has N pixels, the use of separate Red,

Green and Blue signals, increases the total number of

pixels for projection system 800 to 3*N. Further, these

pixels are rectangular in shape, which may be

inconvenient in dimensioning the final screen projection.

Another measure to consider is the final screen

15   luminance of whites generated by projection system 800.

Assume L is the final screen luminance of whites in a

field sequential projection system using a single

reflecting lightvalve array with a polarizing cube.

20   Then, the final screen luminance of the projection system

800 could be expressed as A*3*L, where A is the ratio of

the area of the shortest stripe of the filter of the

projection to the total filter area. For instance, if

the filter 710 of **Figure 7(a)** is used, and if the widths

25   of three stripes are equal, then the top and bottom

stripes have an area of 0.28 of that of the total filter,

while the center stripe has an area of 0.44 of that of

the total filter. In such a case, the final screen

luminance would be 0.28*3*L or 0.84*L which is less than

5   the final screen luminance of a field sequential system

by 16% ignoring any differences in the light losses

between the polarizing cube and the lenticular optics.

Figure 9 illustrates a spherical lenticular

projection system with a transmitting lightvalve array.

10   Projection system 900 consists first of a lamp 910 which

is typically a spherical light source with a reflector.

Lamp 910 sends light to a condenser 920 which refracts

that light to become spatially uniform. The light from

the output of condenser 920 passes through a transmitting

array 930. Transmitting array 930 includes a lightvalve

array covered by a lenticular array, which in this

embodiment, has a field of spherical lenticules, such as

the one illustrated in **Figure 6(a)**.

In non-lenticular projection systems (e.g. slide

20   projection or motion picture systems), the red, green,

and blue exposures occur on the film at positions such

that the light, during projection, retraces its path.

There is therefore no problem caused by the rays near the

edges of the picture not being at right angles to the

25   lenticular array. When using lenticules with a

lightvalve array (transmitting array 930), a field lens

940 is used to ensure that the central beam to the

projection lens is always at right angles to the

lenticules in all parts of the picture. Alternatively,

5   the lenticular array can be used in the manufacture of

the light valve pixels to position them appropriately to

allow for the angles of the light at different parts of

the picture.

The function of field lens 940 is to transform beams

10   of light filling certain angular bands into spatial

ranges at the aperture stop of a projection lens 960.

Light emerging from the field lens 940 is first passed

through filter 950. Since the lenticular array of the

transmitting array 930 consists of spherical lenticules,

15   filter 950 could be similar to filter 720 depicted in

Figure 7(b), having a quarter segment of Red, quarter

segment of Green, quarter segment of Blue and an extra

quarter segment of a primary color. The arrangement of

these segments would depend on the pattern of the pixels

20   in the transmitting array 930. The Red rays will pass

through the Red segment(s) of the filter 950, the Blue

rays will pass through the Blue segment(s) of filter 950

and the Green rays will pass through the Green segment(s)

of filter 950. The projection lens 960 focuses the

25   filtered light output from filter 950 onto a screen or

other destination (not shown). The four rays, Red,

Green, Blue and one of Red, Green or Blue, for a given

pixel, are combined onto one location on that

screen/destination by the projection lens 960. The

5   lenticular array of transmitting array 930, the field

lens 940 and filter 950, in combination with one another

serve to emulate a large mosaic filter placed over a

lightvalve array (as was depicted in **Figure 3** and **Figure

4**) with less expense. Interference filters, such as

10   filter 950, may be used over the projection lens 960 to

maximize their transmittance.

Projection system 900 is advantageous in that the

mosaic filter is avoided and replaced instead by embossed

lenticules (over the lightvalve array of transmitting

15   array 930). Compared to a field sequential projection

system, which has N pixels, the use of separate Red,

Green and Blue signals and an extra primary color signal,

increases the total number of pixels for projection

system 900 to 4*N. Compared to projection system 800,

20   which uses rectangular shaped pixels, projection system

900 has the advantage of using square shaped pixels.

Another measure to consider is the final screen

luminance of whites generated by projection system 900.

Assume L is the final screen luminance of whites in a

25   field sequential projection system using a single

reflecting lightvalve array with a polarizing cube. In

one embodiment, the final screen luminance of the

projection system 900 could be expressed as A*3*L, where

A is the ratio of the area of a segment of the filter of

5   the projection to the total filter area. In this

embodiment, if filter 950 is of the same type as RGB

filter 720 of **Figure 7(b)**, since the area of the segments

are equal, then each segment would have an area of 0.25

of that of the total filter. In such a case, the final

10   screen luminance would be 0.25*3*L or 0.75*L which is

less than the final screen luminance of a field

sequential system by 25% ignoring any differences in the

light losses between the polarizing cube and the

lenticular optics.

In alternate embodiments, where filter 950 is of

the same type as RGBW filter 730 of **Figure 7(c)**, then the

filter 950 would have a quarter segment of Red, quarter

segment of Green, quarter segment of Blue and an extra

quarter segment of white (colorless). The number of

20   pixels does not change and is 4*N. However, the final

screen luminance is improved by a factor of 1/3, since

the extra White ray adds 0.25 of pure white luminance to

the total luminance of each output pixel. Thus, the

final screen luminance would be 1.0*L (0.75*L + 0.25*L),

25   which is identical to that of field sequential systems.

The addition of a luminance signal as the fourth signal

increases the total transmittance of the three primary

colors. While this may be advantageous, implementing

such an embodiment may also need special signal

5   processing techniques that can handle Red, Green, Blue

and pure luminance components in the final image.

In alternate embodiments, if other arrays are used,

any difference between the transmittance factor of a

transmitting array and the reflectance factor of a

10   reflecting array used in the field sequential system will

affect the final screen luminance. However, for

chromaticities of higher purity produced by a mixture of

red, green, blue and white filters, the maximum

luminances relative to that of a white signal are reduced

15   by factors of between 1 and 0.75 below those of pure RGB

filtering systems. Or if a both arrays are reflecting

lenticular arrays, the reflectance factor.

Figure 10 illustrates a lenticular projection system

with a reflecting chrominance array and transmitting

20   luminance array. In projection system 1000, the display

signals are separated into chrominance and luminance

components. A true chrominance display has constant

luminance, and this would have to be produced by the

triplets of pixels (in the cylindrical lenticular

25   methods). For the luminance to be constant for all groups

of pixels, it would have to be constant for all

chromaticities within the display gamut. This means that

the luminance level would have to be that of the

chromaticity whose maximum luminance is the lowest.

5   Typically, broadcast television saves bandwidth, but due

to the effects of gamma correction, some of the luminance

is carried by the chrominance signals. Such signals where

some luminance is carried is referred to as "pseudo-

chrominance" signals. Systems with pseudo-chrominance

10   signals also have what are referred to as "pseudo-

luminance" signals that carry only part of the total

luminance.

The display of projection system 1000 is initiated

by a lamp 1010 which is typically a spherical light

15   source. The light supplied by lamp 1010 is shone into an

condenser 1020. Condenser 1020 causes the light from

lamp 1010 to become spatially uniform. The light is

first passed through a polarizing cube 1060 which allows

any light arriving in a given direction X to pass through

20   its hypotenuse while reflecting back any light

perpendicular to that direction X.

On a lenticular reflecting chrominance array 1030,

the chrominance signal is used to produce, in each group

of three pixels underneath a cylindrical lenticule, the

25   levels required to generate an image. Correspondingly, a

filter 1070 is placed proximate to the projection lens

1090. Filter 1070 is similar to filter 710 of **Figure**

7(a) in that it consists of three stripes, one Red, one

Green and one Blue, matching the pattern of pixels in

5   lenticular array 1030. After passing through the red,

green, and blue stripes of filter 1070 on the projection

lens 1090, these signal levels result in the chrominance

features of the picture being displayed at constant

luminance. Placed close to the lenticulated surface

10   covering the reflecting chrominance array 1030 is a

transmitting luminance lightvalve array 1040 such as can

be provided by an array of transmitting LCD cells. The

luminance signal is applied to the transmitting array

1040. The projection lens 1090 focuses the light

15   controlled by this luminance array signal sharply on the

output screen or destination (not depicted).

To summarize, the lenticular reflecting chrominance

array 1030 modulates the chrominance component of the

image. The transmitting luminance lightvalve array 1040,

20   separately and independently of the array 1030, modulates

the luminance component of the image. This has the

advantage of being able to use a smaller array for the

chrominance component at higher resolutions. The

separately modulated luminance and chrominance components

pass through the polarizing cube 1060 and at the

projection lens 1090.

The total number of pixels in projection system 1000

depends upon the number of RGB triplets of pixels that is

5   required, since the lenticular array 1030 uses

cylindrical lenticules, in this embodiment. The middle

stripe of filter being red enables 57% (assuming all

three filter stripes are of equal width, and a circular

filter) more red light than in the case of the field

10   sequential system. Hence the reduction in luminance

would be only to about 47% instead of to about 30%, if

the luminance was equal to the maximum attainable at the

chromaticity of the red phosphor. If a pseudo-chrominance

signal is used that had the maximum attainable luminance

15   at all chromaticities, there would again be no reduction

in luminance, and there would be less luminance to be

carried by the pseudo-chrominance signal at all

chromaticities involving the red light. This may ensure

that the increase in the number of pseudo-chrominance

20   triplets need only be to one for every nine "pseudo-

luminance" (carrying only part luminance) pixels. Thus,

the total number of pixels would be equal to 3*(1/9)*N+N

= 1.33*N.

To decrease the total number of pixels in the above

25   methods, the pseudo-chrominance and pseudo-luminance may

be replaced instead by a pure chrominance and pure luminance signals. It is then possible, as has been shown in the art, to use one sixteenth as many triplets of chrominance pixels as luminance pixels. The number of pixels required is then N for the luminance display, and (3/16)*N for chrominance, making a total of (19/16)*N. Compared to projection system 1000 using pseudo-chrominance, this has the advantage that the number of pixels is only (19/16)*N = 1.19*N instead of 1.33*N. A disadvantage is that the chrominance display will absorb some of the light. The differences in this regard are described below in the section entitled "Transmittance of chrominance and pseudo-chrominance" displays.

The final screen luminance of system 1000 has a value reduced by any reduction in luminance caused by the pseudo-chrominance display (if used) and the absorption in the additional transmitting luminance array 1040. Alternatively, the final screen luminance may be reduced by the difference between the transmittance factor of two transmitting arrays, if used, and the reflectance factor of the reflecting array 1030 or the transmittance factor of a single transmitting array. As described, the final screen luminance of the projection system 1000 could be expressed as A*3*Y, where A is the ratio of the area of the shortest stripe of the filter of the projection to

the total filter area, and Y a reduction factor. For

instance, if the filter 710 of **Figure 7(a)** is used, and

if the widths of three stripes are equal, then the top

and bottom stripes have an area of 0.28 of that of the

5   total filter, while the center stripe has an area of 0.44

of that of the total filter. In such a case, the final

screen luminance would be 0.28*3*Y or 0.84*Y. The

reduction factor Y is the difference between the

transmittance factor of two transmitting arrays, if used,

10   and the reflectance factor of the reflecting array or the

transmittance factor of a single transmitting array.

Projection system 1000 is described in the above

embodiment as using a lenticular reflecting array 1030

that has cylindrical lenticules and a RGB three-striped

15   filter 1070. In alternate embodiments, the lenticular

reflecting chrominance array 1030 may instead be composed

of spherical lenticules (such as spherical lenticules 610

of **Figure 6(a)**). In one such alternate embodiment, the

corresponding filter 1070 may instead be a four-segment

20   RGB filter (such as filter 720 of **Figure 7(b)**). The

number of quadruplets for pseudo-chrominance is (1/9)*N,

with the total number of pixels at 4*(1/9)*N + N =

(13/9)*N or 1.44*N. The final screen luminance of such a

projection system is 0.75 (the fractional area of a

25   single segment multiplied by 3) multiplied by the

reduction factor Y. The reduction factor Y is the difference between the transmittance factor of two transmitting arrays, if used, and the reflectance factor of the reflecting array or the transmittance factor of a

5   single transmitting array. As depicted, the final screen luminance would be 0.75*R, which is the reflectance factor of the reflecting array.

In another such alternate embodiment, where the lenticular array 1030 uses spherical lenticules, the

10   corresponding filter 1070 may instead be a four-segment RGBW filter (such as filter 730 of **Figure 7(c)**). The extra luminance carried by the chrominance array (due to the extra white pure luminance in the filter) causes the number of quadruplets of pixels for pseudo-chrominance to

15   be (1/4)*N. Thus the total number of pixels is 4*(1/4)*N plus N for a total of 2*N. The final screen luminance is a total of 1.0 multiplied by the reduction factor Y. The reduction factor Y is the difference between the transmittance factor of two transmitting arrays, if used,

20   and the reflectance factor of the reflecting array or the transmittance factor of a single transmitting array.

Figure 11 illustrates a lenticular projection system with a reflecting chrominance array and reflecting luminance array. The display of projection system 1100

25   is initiated by a lamp 1110 which is typically a

spherical light source. The light supplied by lamp 1110

is shone into an condenser 1120. Condenser 1120 causes

the light from lamp 1110 to become spatially uniform.

These rays are first passed through a first polarizing

5   cube 1150 which allows any light arriving in a given

direction X to pass through its hypotenuse while

reflecting back any light perpendicular to that direction

X.

On a lenticular reflecting chrominance array 1130,

10   the chrominance signal is used to produce, in each group

of three pixels underneath a cylindrical lenticule, the

levels required to generate an image. Correspondingly, a

filter 1160 is placed proximate to a relay lens 1170.

Filter 1160 is similar to filter 710 of **Figure 7**(a) in

15   that it consists of three stripes, one Red, one Green and

one Blue, matching the pattern of pixels in lenticular

array 1130. After passing through the red, green, and

blue stripes of filter 1160 on the relay lens 1170, these

signal levels display the chrominance features of the

20   picture at constant luminance.

The relay lens 1170 images the reflecting

chrominance array 1130 on to a reflecting luminance array

1180. The relay lens 1170 also places thereby the

modulated chrominance component of the image into the

second polarizing cube 1175. The use of relay lens 1170

in the optical path prior to the main projection lens

1190 results in some loss of definition and increase in

flare. It also introduces the need for registration of

5   the image produced by the relay lens 1170 on the second

light-valve array 1180. However, the fact that only the

low definition image passes through the relay lens 1170

greatly alleviates the importance of these factors. The

relay lens 1170 makes it possible to reduce the size of

10   the reflecting chrominance array 1130 and thus can reduce

its cost. With the number of chrominance pixels being

(3/9)N (see below), for pixels of the same area in the

chrominance array 1130, its total area can be reduced to

one third.

15   The total number of pixels in projection system 1100

depends upon the number of RGB triplets of pixels that is

required, since the lenticular array 1130 uses

cylindrical lenticules, in this embodiment. The middle

stripe of filter being red enables 57% (assuming all

20   three filter stripes are of equal width, and a circular

filter) more red light than in the case of the field

sequential system. Hence the reduction in luminance

would be only to about 47% instead of to about 30%, if

the luminance was equal to the maximum attainable at the

25   chromaticity of the red phosphor. If a pseudo-chrominance

signal is used that had the maximum attainable luminance
at all chromaticities, there would again be no reduction
in luminance, and there would be less luminance to be
carried by the pseudo-chrominance signal at all

5   chromaticities involving the red light. This may ensure
that the increase in the number of pseudo-chrominance
triplets need only be to one for every nine "pseudo-
luminance" (carrying only part luminance) pixels. Thus,
the total number of pixels would be equal to $3*(1/9)*N+N$

10   $= 1.33*N$.

To decrease the total number of pixels in the above
methods, the pseudo-chrominance and pseudo-luminance may
be replaced instead by a pure chrominance and pure
luminance signals. It is then possible, as has been

15   shown in the art, to use one sixteenth as many triplets
of chrominance pixels as luminance pixels. The number of
pixels required is then N for the luminance display, and
$(3/16)*N$ for chrominance, making a total of $(19/16)*N$.
Compared to projection system 1100 using pseudo-

20   chrominance, this has the advantage that the number of
pixels is only $(19/16)*N = 1.19*N$ instead of $1.33*N$. A
disadvantage is that the chrominance display will absorb
some of the light. The differences in this regard are
described below in the section entitled "Transmittance of

25   chrominance and pseudo-chrominance" displays.

The final screen luminance of system 1100 has a
value reduced by any reduction in luminance caused by the
pseudo-chrominance display (if used) and the absorption
in the additional reflecting luminance array 1180.

5   Alternatively, the final screen luminance may be reduced
by the difference between the transmittance factor of two
transmitting arrays, if used, and the reflectance factor
of the reflecting array 1130 or the transmittance factor
of a single transmitting array. As described, the final
10   screen luminance of the projection system 1100 could be
expressed as A*3*Y, where A is the ratio of the area of
the shortest stripe of the filter of the projection to
the total filter area, and a reduction factor. For
instance, if the filter 710 of **Figure 7(a)** is used, and
if the widths of three stripes are equal, then the top
15   and bottom stripes have an area of 0.28 of that of the
total filter, while the center stripe has an area of 0.44
of that of the total filter. In such a case, the final
screen luminance would be 0.28*3*R or 0.84*R. The
20   reduction factor R is the reflectance factor of the
reflecting array since only reflecting arrays are used.

       Projection system 1100 is described in the above
embodiment as using a lenticular reflecting array 1130
that has cylindrical lenticules and using a RGB three-
25   striped filter 1160. In alternate embodiments, the

lenticular reflecting chrominance array 1130 may instead
be composed of spherical lenticules (such as spherical
lenticules 610 of **Figure 6(a)**). In one such alternate
embodiment, the corresponding filter 1160 may instead be
a four-segment RGB filter (such as filter 720 of **Figure
7(b)**). The number of quadruplets for pseudo-chrominance
is $(1/9)*N$, with the total number of pixels at $4*(1/9)*N$
$+ N = (13/9)*N$ or $1.44*N$. The final screen luminance of
such a projection system is 0.75 (the fractional area of
a single segment multiplied by 3) multiplied by the
reflectance factor of the reflecting array since only
reflecting arrays are used.

In another such alternate embodiment where the
lenticular array 1130 uses spherical lenticules, the
corresponding filter 1160 may instead be a four-segment
RGBW filter (such as filter 730 of **Figure 7(c)**). The
extra luminance carried by the chrominance array (due to
the extra white pure luminance in the filter) causes the
number of quadruplets of pixels for pseudo-chrominance to
be $(1/4)*N$. Thus the total number of pixels is $4*(1/4)*N$
plus N for a total of $2*N$. The final screen luminance is
a total of 1.0 multiplied by the reflectance factor of
the reflecting array since only reflecting arrays are
used.

Figure 12 illustrates a lenticular projection system

with a transmitting chrominance array and reflecting

luminance array. The display of projection system 1200

is initiated by a lamp 1210 which is typically a

5   spherical light source. The light supplied by lamp 1210

is shone into an condenser 1220. Condenser 1220 causes

the light from lamp 1210 to become spatially uniform.

These rays are first passed through a first polarizing

cube 1250 which allows any light arriving in a given

10   direction X to pass through its hypotenuse while

reflecting back any light perpendicular to that direction

X. The purpose of polarizing cube 1250 is to polarize

light rays if the transmitting chrominance array 1230 is

an LCD array.

On a lenticular transmitting chrominance array 1230,

the chrominance signal is used to produce, in each group

of three pixels underneath a cylindrical lenticule, the

levels required to generate a chrominance image.

Correspondingly, a filter 1260 is placed proximate to a

20   relay lens 1270. Filter 1260 is similar to filter 710 of

Figure 7(a) in that it consists of three stripes, one

Red, one Green and one Blue, matching the pattern of

pixels in lenticular array 1230. After passing through

the red, green, and blue stripes of filter 1260 on the

25   relay lens 1270, these signal levels result in the

chrominance features of the picture being displayed at constant luminance. The relay lens 1270 images the transmitting chrominance array 1230 on to a reflecting luminance array 1280. The use of relay lens 1270 in the

5   optical path prior to the main projection lens 1290 results in some loss of definition and increase in flare. It also introduces the need for registration of the image produced by the relay lens 1270 on the second light-valve array 1280. Polarizing cube 1275 allows any light

10 arriving in a given direction X to pass through its hypotenuse while reflecting back any light perpendicular to that direction X. The purpose of polarizing cube 1275 is to combine the luminance and chrominance components of the image, and to allow the reflecting luminance array

15 1280 to modulate the input chrominance image. However, the fact that only the low definition image passes through the relay lens 1270 greatly alleviates the importance of these factors. The relay lens 1270 makes it possible to reduce the size of the reflecting

20 chrominance array 1130 and thus can reduce its cost. With the number of chrominance pixels being (3/9)N (see below), for pixels of the same area in the chrominance array 1230, its total area can be reduced to one third.

The total number of pixels in projection system 1200

25 depends upon the number of RGB triplets of pixels that is

required, since the lenticular array 1230 uses

cylindrical lenticules, in this embodiment. The middle

stripe of filter being red enables 57% (assuming all

three filter stripes are of equal width, and a circular

5   filter) more red light than in the case of the field

sequential system. Hence the reduction in luminance

would be only to about 47% instead of to about 30%, if

the luminance was equal to the maximum attainable at the

chromaticity of the red phosphor. If a pseudo-chrominance

10   signal is used that had the maximum attainable luminance

at all chromaticities, there would again be no reduction

in luminance, and there would be less luminance to be

carried by the pseudo-chrominance signal at all

chromaticities involving the red light. This may ensure

15   that the increase in the number of pseudo-chrominance

triplets need only be to one for every nine "pseudo-

luminance" (carrying only part luminance) pixels. Thus,

the total number of pixels would be equal to 3*(1/9)*N+N

= 1.33*N.

20   To decrease the total number of pixels in the above

methods, the pseudo-chrominance and pseudo-luminance may

be replaced instead by a pure chrominance and pure

luminance signals. It is then possible, as has been

shown in the art, to use one sixteenth as many triplets

25   of chrominance pixels as luminance pixels. The number of

pixels required is then N for the luminance display, and

(3/16)*N for chrominance, making a total of (19/16)*N.

Compared to projection system 1200 using pseudo-

chrominance, this has the advantage that the number of

5   pixels is only (19/16)*N = 1.19*N instead of 1.33*N. A

disadvantage is that the chrominance display will absorb

some of the light. The differences in this regard are

described below in the section entitled "Transmittance of

chrominance and pseudo-chrominance" displays.

10   The final screen luminance of system 1200 has a

value reduced by any reduction in luminance caused by the

pseudo-chrominance display (if used) and the absorption

in the additional transmitting luminance array 1240.

Alternatively, the final screen luminance may be reduced

15   by the difference between the transmittance factor of two

transmitting arrays, if used, and the reflectance factor

of the reflecting array 1230 or the transmittance factor

of a single transmitting array. As described, the final

screen luminance of the projection system 1200 could be

20   expressed as A*3*T, where A is the ratio of the area of

the shortest stripe of the filter of the projection to

the total filter area, and a reduction factor T. For

instance, if the filter 710 of **Figure 7(a)** is used, and

if the widths of three stripes are equal, then the top

25   and bottom stripes have an area of 0.28 of that of the

total filter, while the center stripe has an area of 0.44

of that of the total filter. In such a case, the final

screen luminance would be 0.28*3*T or 0.84*T. The

reduction factor T is the transmittance factor of the

5   transmitting array 1230.

Projection system 1200 is described in the above

embodiment as using a lenticular transmitting array 1230

that has cylindrical lenticules and using a RGB three-

striped filter 1260. In alternate embodiments, the

10   lenticular transmitting chrominance array 1230 may

instead be composed of spherical lenticules (such as

spherical lenticules 610 of **Figure 6(a)**). In one such

alternate embodiment, the corresponding filter 1160 may

instead be a four-segment RGB filter (such as filter 720

15   of **Figure 7(b)**). The number of quadruplets for pseudo-

chrominance is (1/9)*N, with the total number of pixels

at 4*(1/9)*N + N = (13/9)*N or 1.44*N. The final screen

luminance of such a projection system is 0.75 (the

fractional area of a single segment multiplied by 3)

20   multiplied by the transmittance factor T of the

transmitting array 1230.

In another such alternate embodiment where the

lenticular array 1230 uses spherical lenticules, the

corresponding filter 1260 may instead be a four-segment

25   RGBW filter (such as filter 730 of **Figure 7(c)**). The

extra luminance carried by the chrominance array (due to

the extra white pure luminance in the filter) causes the

number of quadruplets of pixels for pseudo-chrominance to

be (1/4)*N. Thus the total number of pixels is 4*(1/4)*N

5   plus N for a total of 2*N. The final screen luminance is

a total of 1.0 multiplied by T, the transmittance factor

of the transmitting array 1230.

Transmittance of Chrominance versus Pseudo-chrominance

10   A true chrominance display has constant luminance,

and this would have to be produced by the triplets of

pixels (in the cylindrical lenticular methods) or by the

quadruplets of pixels (in the spherical lenticular

methods). For the luminance to be constant for all

15   groups of pixels, it would have to be constant for all

chromaticities within the display gamut. This implies

that the luminance level would have to be that of the

chromaticity whose maximum luminance is the lowest.

In the cylindrical lenticular methods, the luminance

20   of the blue primary is always the lowest, and is lower

than that of the display white by a large factor,

typically representing a reduction to about 10%. This

would imply that the luminance-chrominance displays would

be only one tenth of the luminance of the RGB lenticular

25   display system 800 of **Figure 8**. However, it is known in

the field of broadcast television that considerable

savings in bandwidth can be made even when, because of

the effects of gamma correction, some of the luminance is

carried by the chrominance signals (referred to as

pseudo-chrominance signals). If a pseudo-chrominance

5   signal was used in which the luminance was equal to the

maximum attainable at the chromaticity of the red

phosphor where possible, and elsewhere was the maximum

attainable, the reduction in luminance would only be to

about 30%. This would result in chromaticities near

10   those of the blue phosphor having part of their luminance

displayed by the low-definition pseudo-chrominance

display. But, since the human eye has poor resolution of

blue light, any reduction in picture definition would be

negligibly small.

15   If a pseudo-chrominance signal were used in which

the luminance was equal to the maximum attainable at the

chromaticity of the green phosphor where possible, and

elsewhere was the maximum attainable, the reduction in

luminance would only be to about 60%. This would result

20   in chromaticities near those of the blue and red

phosphors having part of their luminance displayed by the

low-definition display. Again since the eye has poorer

resolution of red light than of white light, any

reduction in picture definition would not be large.

Finally, if a pseudo-chrominance signal were used in which the luminance was equal to the maximum attainable at all chromaticities, there would be no reduction in luminance. This would result in all chromaticities other

5   than those of the display white having part of their luminance displayed by the low-definition display. Again since the eye has poorer resolution of colored light than of white light, the reduction in picture definition would be limited. The reduction could be ameliorated by

10   increasing the number of triplets for pseudo-chrominance from one for every sixteen pseudo-luminance pixels to one for every four, for instance, making a total number of pixels equal to $(3/4 + 4/4)N = (7/4)N$.

The pixel count can be further modified by choosing

15   the center stripe on the projection lens to be used for the red filter. On a circular lens this results in there being about 57% more red light than in the case of the field sequential system. Hence the reduction in luminance would be only to about 47% instead of to about

20   30%, if the luminance was equal to the maximum attainable at the chromaticity of the red phosphor. If the pseudo-chrominance signal had the maximum attainable luminance at all chromaticities, there would again be no reduction in luminance. In fact, there would be less luminance to

25   be carried by the pseudo-chrominance signal at all

chromaticities involving the red light. This might

ensure that the increase in the number of pseudo-

chrominance triplets need only be to one for every nine

pseudo-luminance pixels making a total number of pixels

5   equal to (3/9 + 9/9)*N = 1.33*N, which is described in

the embodiments above.

In spherical lenticular systems, using four colored

elements, the luminance of the blue primary is also

always the lowest and lower than that of the display

10   white by a large factor. If two of the elements were red

and a pseudo-chrominance signal were used in which the

luminance was equal to the maximum attainable at the

chromaticity of the two red elements (phosphors), and

elsewhere was the maximum attainable, the reduction in

15   luminance would only be to about 60%. Again, this would

result in chromaticities near those of the blue phosphor

having part of the their luminance displayed by the low

definition display with the poor blue resolution by the

human eye resulting in only negligibly small effects. If

20   a pseudo-chrominance signal had the maximum at all

chromaticities, there would again be no reduction in

luminance. This would again result in all chromaticities

other than those of the display white having part of

their luminance displayed by the low-definition display.

25   However, compared to the cylindrical lenticular methods,

the effects would be reduced by the double area of red.
Also, the poorer resolution of the eye to colored light
than to white light will again reduce the apparent
effects. If these effects were not negligible, they

5   could again be allowed for by increasing the number of
pseudo-chrominance quadruplets from one for every sixteen
luminance pixels to one for every nine, making a total
number of pixels equal to $(4/9 + 9/9)*N = (13/9)*N$, that
is $1.44*N$.

10   In the spherical lenticular methods using red,
green, blue, and colorless segments in the filter, the
luminance of the blue primary will be lower than that of
the display white by an even larger factor. The number
of pseudo-chrominance groups then has to be increased to

15   one for every four pseudo-luminance pixels, making a
total number of pixels of $(4/4 + 1)*N$, or $2*N$.

Using Mosaics or Prism Assemblies

Instead of cylindrical lenticular chrominance
systems, mosaics of red, green, and blue areas can be

20   used. In the case of the spherical lenticular
chrominance systems, mosaics of a red area, a green area,
a blue area, and a red or green or blue area can be used,
or mosaics of a red area, a green area, a blue area, and
a colorless area can be used. The advantage of using

25   mosaics instead of lenticular systems is that the

complications of the lenticular optics are avoided. One

disadvantage is that, because filters in mosaics have to

be made of dyes rather than of the dichroic materials

which can be used in lenticular systems, the displays

5   have luminances reduced to about 30%.

Instead of the lenticular chrominance arrays in

systems shown in systems 1000 and 1100, a dichroic prism

assembly with three lightvalve arrays can be used. The

loss of light caused by the filter wheel in the field

10   sequential system or by the filter arrays in the mosaic

and lenticular systems, is avoided in the prism assembly

by the superimposition of the three images optically

using dichroic reflectors. This gain in efficiency,

potentially by a factor of three, makes it possible to

15   use a pseudo-chrominance signal the luminance of which is

only one third of that of the white. This still achieves

a system in which the luminance of the white is not

reduced relative to that of the field sequential system

(except for absorptions in the prism assembly and in the

20   second light-valve arrays). The reduction of the

chrominance display to one-third of that of the white

means that luminance is carried by it only for bluish

colors to which the eye is not very sensitive. The

number of pixels in the three chrominance arrays need

25   therefore be only one sixteenth of those in the luminance

array, making a total number of pixels of (3/16 + 1)*N =

(19/16)*N = 1.19N. The small number of pixels required

in each of the chrominance arrays means that, for the

same size of pixel, these arrays need be only one

5   sixteenth of the area of the luminance array thus

lowering their cost dramatically. The prism assembly can

also be greatly reduced in size, again lowering cost.

The need for exact registration of the three chrominance

arrays is also alleviated by their being only used for

10 the low-definition chrominance display.

COMPARISON TABLE OF ALL PROJECTION SYSTEMS

Projection system	Lenticule /System	Filters	Chromin. Array / Lumin. Array	Pixel Shape	Pixels	White Lum.
	Field Seq.	RGB	Refl.			1
	Prism Ass.	RGB	Refl.		3N	3P
100 (3 lamps)	Triple Proj.	RGB	Trans. or Refl.		3N	3
200 (1 lamp)	Triple Proj.	RGB	Trans. or Refl.		3N	1
400	Mosaic	RGB	Refl.	Square	3N	0.30
800	Cyl.	RGB	Trans. or Refl.	Rectangular	3N	0.84X
900	Sph.	RGBR	Trans. or Refl.	Square	4N	0.75X
900 (filter 730)	Sph	RGBW	Trans. or Refl.	Square	4N	1.00X
1000	Cyl.	RGB	Rfl orTr / Trans	Rectangular	1.33N	0.84Y
1000 (filter 720)	Sph.	RGBR	Rfl orTr / Trans.	Square	1.44N	0.75Y
1000 (filter 730)	Sph.	RGBW	Rfl orTr / Trans.	Square	2.00N	1.00Y
1100	Cyl.	RGB	Refl. / Refl.	Rectangular	1.33N	0.84R
1100 (filter 720)	Sph.	RGBR	Refl. / Refi.	Square	1.44N	0.75R
1100 (filter 730)	Sph.	RGBW	Ref. / Refl.	Square	2.00N	1.00R
1200	Cyl.	RGB	Trans. / Refl.	Rectangular	1.33N	0.84T
1200 (filter 720)	Sph.	RGBR	Trans. / Ref.	Square	1.44N	0.75T
1200 (filter 730)	Sph.	RGBW	Trans. / Ref.	Square	2.00N	1.00T
(no lent.)	Mosaic	RGB		Square	1.33N	0.25T

(no lent.)	Mosaic	RGBR		Square	1.44N	0.22T
(no lent.)	Mosaic	RGBW		Square	2.00N	0.30T
(no lent.)	Prism ass	RGB	Ref. / Trans.	Square	1.19N	1.00PT
(no lent.)	Prism ass.	RGB	Refl. / Ref.	Square	1.19N	1.00PR

In the above table, P is the transmittance factor of prism assembly, T is transmittance factor of transmitting array, R the reflectance factor of reflecting array, and X, the difference between transmittance factor of transmitting array, if used, and reflectance factor of reflecting array. Y is the difference between transmittance factor of two transmitting arrays, if used, and reflectance factor of reflecting array, or T if only one transmitting array is used.

The invention, as described above, refers to "lightvalves" as the light modulation device. However, it will be appreciated by one of ordinary skill in the art, that the principles presented herein can be applied to any type of light modulation device, such as a liquid crystal device or a micro-mirror device. Additionally, while the invention refers to the initial light source as an incandescent lamp, the initial light source may be any kind of illuminant, such an incandescent lamp, a mercury halogen lamp, an array of lasers or powerful LEDs (Light Emitting Diodes).

While the invention has been described with reference to numerous specific details, one of ordinary skill in the art will recognize that the invention can be embodied in other specific forms without departing from

5   the spirit of the invention. Thus, one of ordinary skill in the art will understand that the invention is not to be limited by the foregoing illustrative details, but rather is to be defined by the appended claims.